



HCAT Meeting

20 – 21 July 2004



In Search of the Holy Grail (of EHC Alternatives)

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Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE JUL 2004		2. REPORT TYPE		3. DATES COVERED 00-00-2004 to 00-00-2004	
4. TITLE AND SUBTITLE In Search of the Holy Grail (of EHC Alternatives)				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory, AFRL/MLSC, Wright Patterson AFB, OH, 45433				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES 24th Replacement of Hard Chrome Plating Program Review Meeting, July 20-21, 2004, Park City, UT. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 33	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



My Related Activities



- Non-Line of Sight (NLOS) Hard Chrome Alternatives
- Advanced Non-Line of Sight (ANLOS) Hard Chrome Alternatives
- Cold Spray Coatings Evaluation
- Effects of Chemicals on HVOF Coatings
- Metal Coated Particles Concept Evaluation



Non-Line of Sight (NLOS) Hard Chrome Alternatives



NLOS Hard Chrome Alternatives



- Screening Testing Approach
 - AF supplied the bare steel specimen
 - Each vendor applied its own product in order to eliminate any chance of processing anomalies
 - .005” thick coatings were requested
 - Coatings ground to .003”
 - 2 coating variations
 - As deposited
 - Baked at 375°F/24 hrs



NLOS Hard Chrome Alternatives



Short Term Screening Testing Has Been Completed

Adhesion (bend test)

Hardness (Knopp w/ 100 gram indenter)

Profilometry (Smoothness / leveling ability)

Chemical composition (no unacceptable constituents)

Quality (visual analysis IAW EHC specification)

Taber wear index (weight loss per 1000 test cycles)

- Selected the 4 best processes for further evaluation



NLOS Hard Chrome Alternatives



Niplate 700 by Surface Technology

- Electroless Nickel (95%) – Phosphorous (5%) with silicon carbide particles

UltraCem by Universal Chemical

- Electroless Nickel (95%) – Boron (5%) that forms crystalline clusters of nickel boride

Nanon 9 by Nanon Technologies

- Electrolytic Nickel (50-70%) – Cobalt (30-50%) that forms nanocrystalline microstructure

NiCom by US Chrome

- Electrolytic Nickel w/ silicon carbide particles



NLOS Hard Chrome Alternatives



Short Term Screening Test Results

	Niplate 700	UltraCem	Nanon 9	NiCom
Adhesion	Pass	Pass	Fail: as deposited Pass: 375°F/24 hrs	Fail: as deposited Pass: 375°F/24 hrs
Hardness (EHC \approx 900KNH ₁₀₀)	545 (as deposited) 559 (375°F/24 hrs)	840 (as deposited) 857 (375°F/24 hrs)	770 (as deposited) 830 (375°F/24 hrs)	519 (as deposited) 558 (375°F/24 hrs)
Profilometry	Acceptable	Acceptable	Acceptable	Acceptable
Composition	As Claimed	As Claimed	As Claimed	As Claimed
Quality	Acceptable	Acceptable	Acceptable	Acceptable
Taber Wear Index EHC \approx 2.2 (According to OC-ALC, 10 or less may be acceptable)	2.8 (as deposited) 2.6 (325°F/24 hrs)	9.8 (as deposited) 14.0 (375°F/24 hrs)	12.0 (as deposited) 10.8 (375°F/24 hrs)	9.7 (as deposited) 6.0 (375°F/24 hrs)



NLOS Hard Chrome Alternatives



- Long Term Screening Testing Started May 04
 - Corrosion
 - Fatigue
 - Hydrogen Embrittlement (completed except for Nanon 9)

Unbaked Nicom has been the only failure to date

- Wear (Block on Ring)
- Grindability determination
- Strippability determination



NLOS Hard Chrome Alternatives



- Determine the best alternative
 - Selection of the best process will be based upon screening test results and ALC user input
- Conduct validation testing of the best alternative as applied by ALC plating shops
- Develop ALC implementation plan
- Follow-on project for qualification testing is planned



Advanced Non-Line of Sight (ANLOS) Hard Chrome Alternatives



Advanced Non-Line of Sight (ANLOS) Hard Chrome Alternatives



- Non-chrome, non-nickel containing coatings
- Wet or dry processes
- Available and emerging technologies considered
 - Nano structured and nano material coatings are included
- Alternatives identification phase and initial down-selection to be completed by August 2004
- Technical approach will be similar to the NLOS project



Cold Spray Coatings Evaluation



Cold Spray Coatings

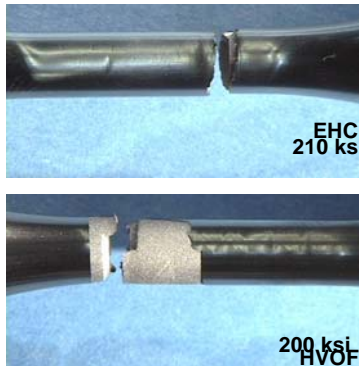


- Unique Coat: AC-HVAF WC-17Co
- Inovati: Kinetic Metallization WC-17Co

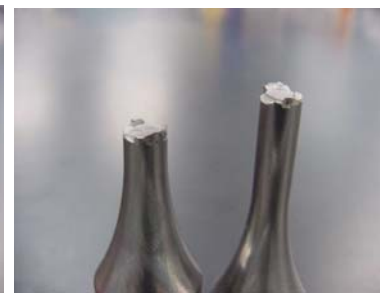
VS

- OO-ALC HVOF WC-17Co
 - Coating Integrity Fatigue Testing
 - Cyclic Corrosion Testing
 - Metallurgical Analysis

This project based upon promising results of previous investigation



AC-HVAF 185 ksi



AC-HVAF 220 ksi



Cold Spray Coatings Evaluation



- Integrity Testing
 - 2" diameter, 4340, R_c 53, smooth gage specimen
 - 4" long coating patch, ground to .003" and .010"
 - Stress Ratio (R) = $-.33$ & -1 @ .5 Hz
 - Start @ 160 ksi, increase 10 ksi every 20 cycles
 - Photo taken every cycle; NDI as required
 - Acoustic emission to determine onset of coating cracking



Cold Spray Coatings Evaluation



- Corrosion Testing
 - 1" diameter X 6" long 4340, R_c 53 Bars
 - 5" long coating patch, ground to .003" and .010"
 - Cyclic corrosion testing for 1920 hrs
 - Photographs & visual evaluation at least every 168 hrs
- Metallurgical Analysis
 - Carbide distribution must be uniform
 - Interface contamination not > 10%
 - Cracks or delaminates should not exist
 - Voids/oxides not > 1%, no voids > .002"
 - Unmelted particles are not acceptable



Effects of Chemicals on HVOF Coatings



Project Overview



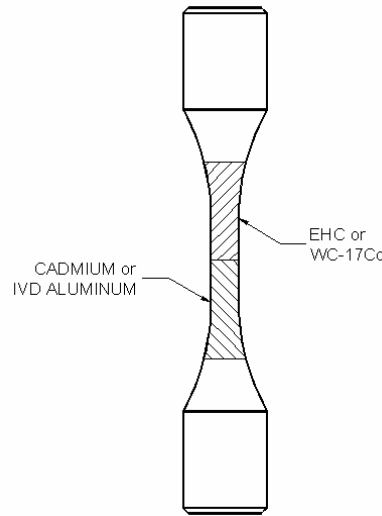
- Environmentally Assisted Cracking / Stress Corrosion Cracking is a major cause of landing gear failures
- Cyclic corrosion testing has shown that HVOF WC-17Co coatings will corrode
- Landing gear have WC-17Co coatings adjacent to IVD aluminum or cadmium
- Landing gear are exposed to various chemicals
- Determine effect of chemical exposure on specimen coated with WC-17Co in contact with IVD aluminum or cadmium while being stressed at a constant load



Testing Approach



1/4" diameter, 4340 steel, Rc53, smooth gage specimen



Duplex coated specimen

- 1/2 coated with WC-17Co, ground to .003"
- 1/2 coated with IVD aluminum or cadmium
- or
- 1/2 coated with EHC, ground to .003"
- 1/2 coated with IVD aluminum or cadmium



Testing Approach



- Specimen exposed to chemicals while subjected to a constant stress of 180 ksi
- Specimen wetted with chemical every 24 hrs
- 150 hrs without failure is considered passing
- Testing stopped after 196 hours



Testing Approach



Test Set-up

- 6 chemicals
 - Type III cleaner
 - Type IV cleaner
 - Aircraft deicer
 - Runway deicer
 - Paint stripper
 - Decontaminant



Chemicals Used for Evaluation



<u>Type</u>	<u>Specification</u>	<u>Name</u>	<u>Manufacturer</u>
Cleaner	MIL-PRF-87937 Type III	Air Force Gel	Space Chemical, Inc.
Cleaner	MIL-PRF-87937 Type IV	Cee Bee A-882	McGean-Rohco, Inc.
A/C Deicer	AMS 1424	Octaflo EF	Octagon Process, Inc.
Runway Deicer	AMS 1435	Cryotech E36	Cryotech Deicing Technology
Paint Stripper	MIL-R-81294	Cee Bee A-235	McGean-Rohco, Inc.
Decontaminant	A-A-1441	MDF-200	Modec, Inc.



Observations So Far

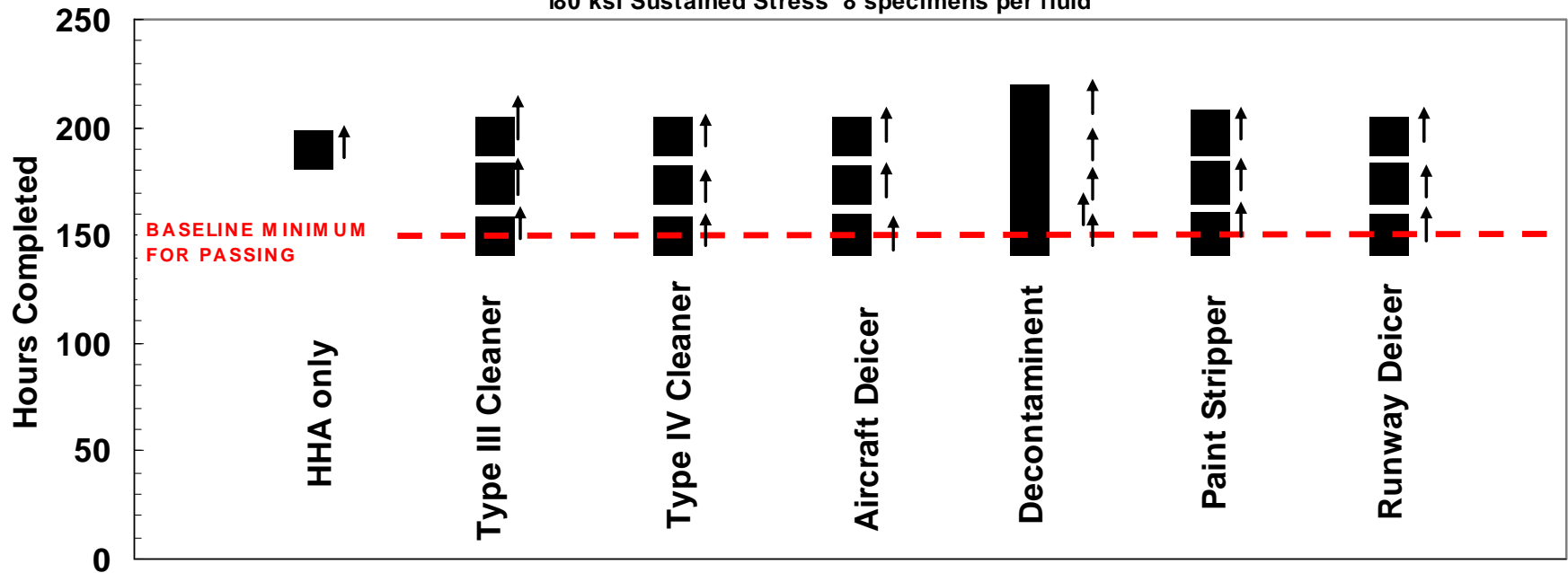


- 100% of 55 EHC / IVD alum specimen passed
- 95% of 19 EHC / cadmium specimen passed
- 50% of 48 WC-17Co / IVD alum specimen passed
- 17% of 12 WC-17Co / cadmium specimen passed
- WC-17Co coatings cracked when stressed to 180 ksi
- WC-17Co coated specimen fail in the WC-17Co region with intergranular initiation
- Supplemental testing of 12 uncoated specimen (2 per chemical) saw only 1 failure prior to 150 hrs



EHC / IVD Al coated 4340 steel specimens in High Humidity Air (HHA) and Various Chemicals

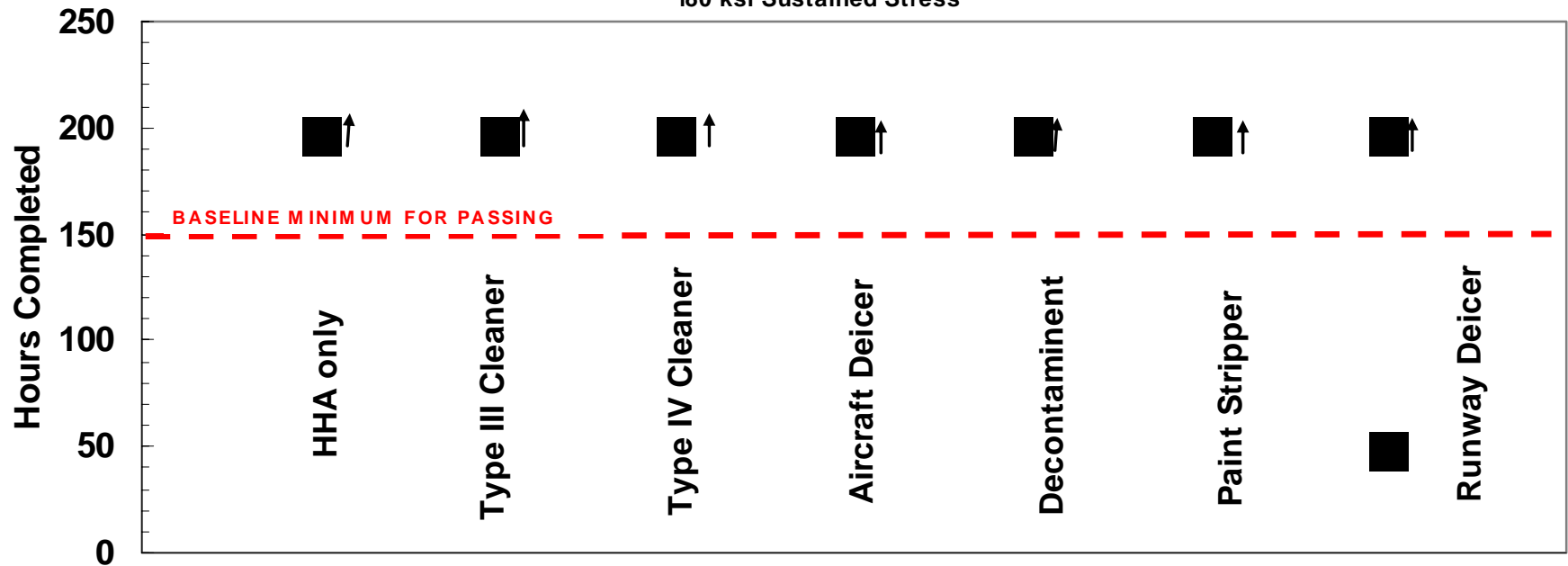
180 ksi Sustained Stress 8 specimens per fluid





EHC / Cadmium coated 4340 steel specimens in High Humidity Air (HHA) and Various Chemicals

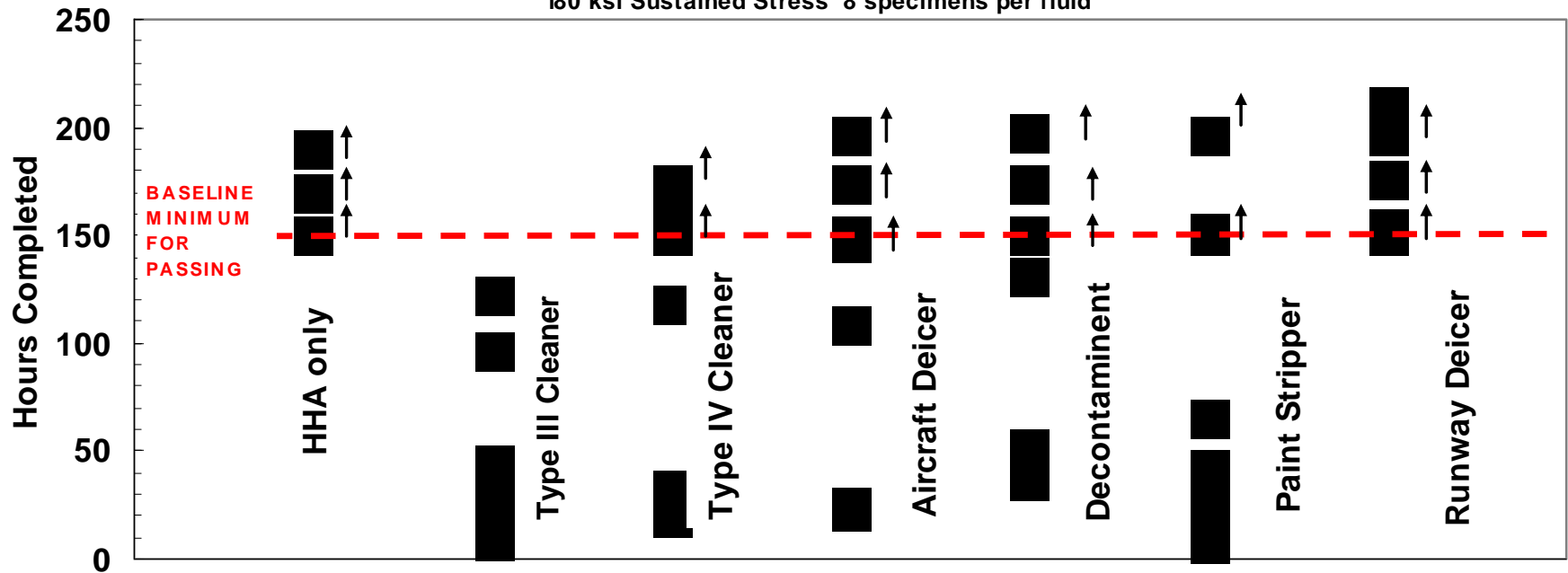
180 ksi Sustained Stress





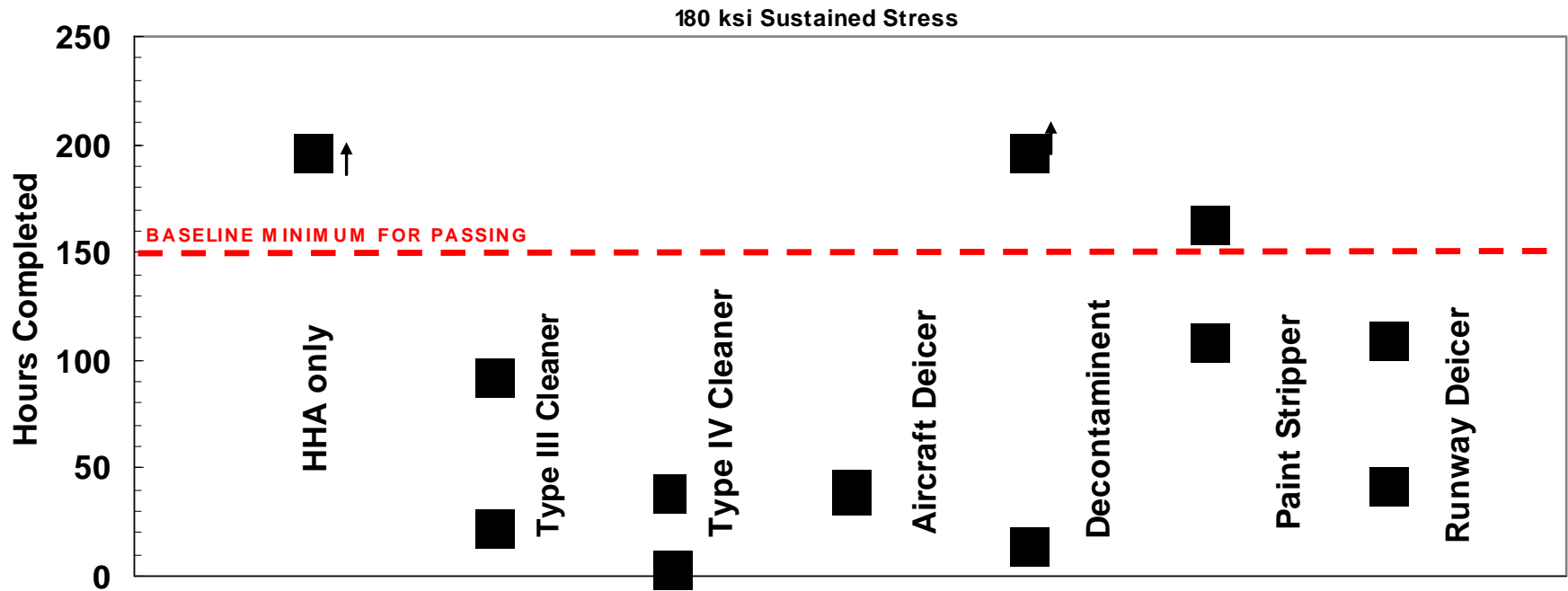
WC-17Co / IVD Al coated 4340 steel specimens in High Humidity Air (HHA) and Various Chemicals

180 ksi Sustained Stress 8 specimens per fluid



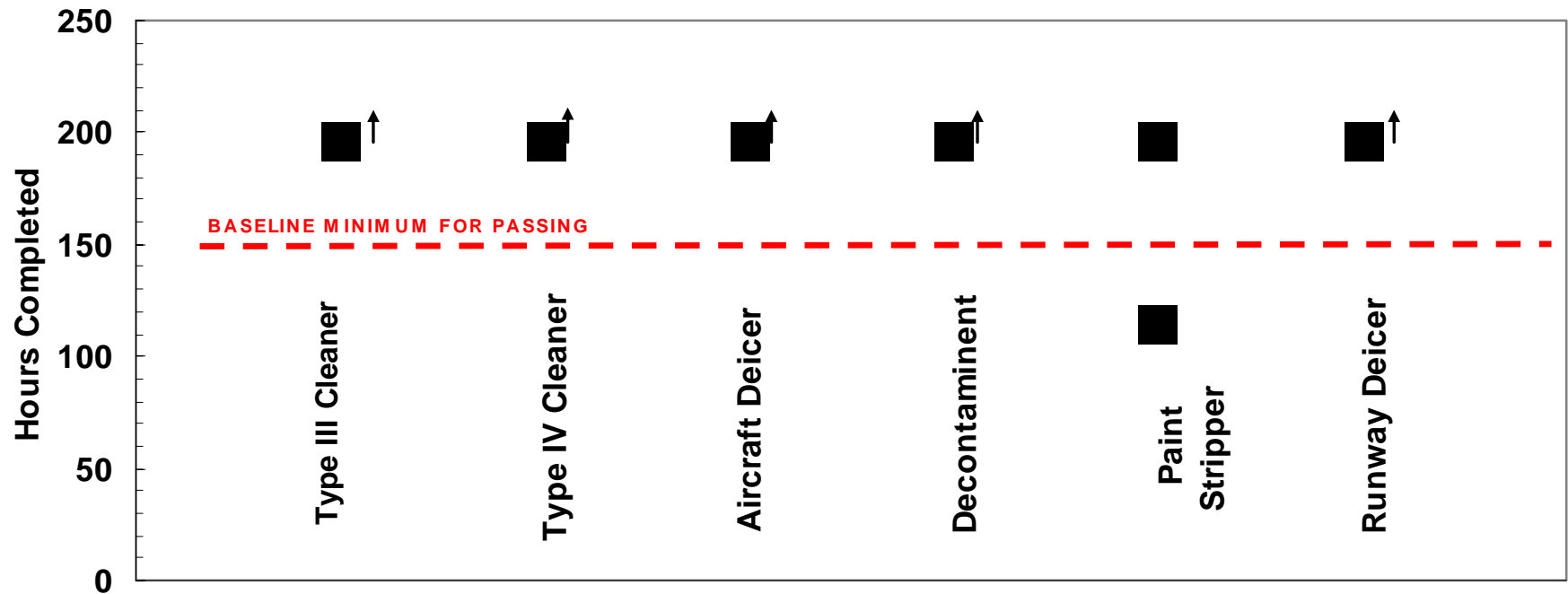


WC-17Co / Cadmium coated 4340 steel specimens in High Humidity Air (HHA) and Various Chemicals



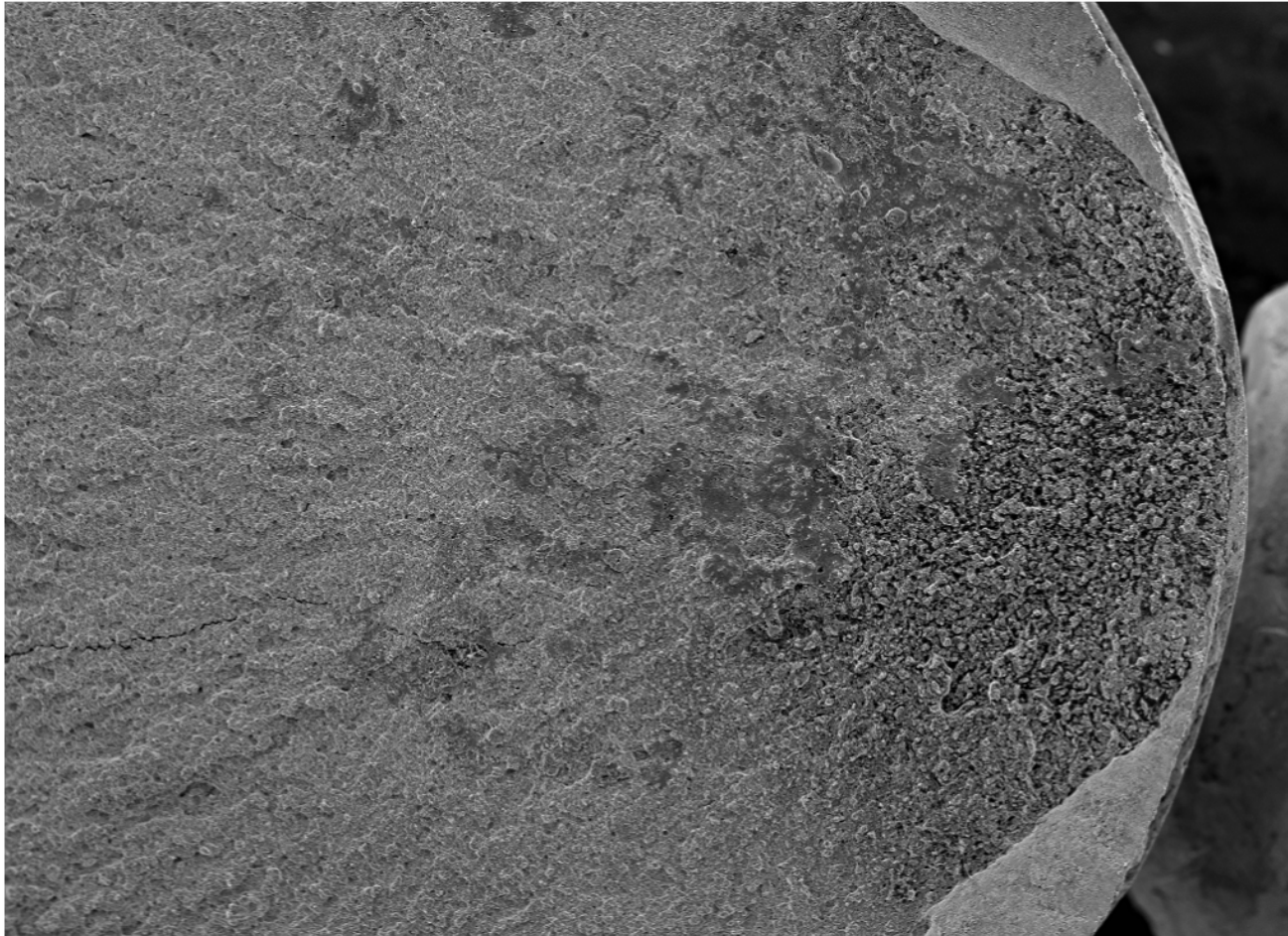


Bare 4340 steel specimens in High Humidity Air (HHA) and Various Chemicals 180 ksi Sustained Stress





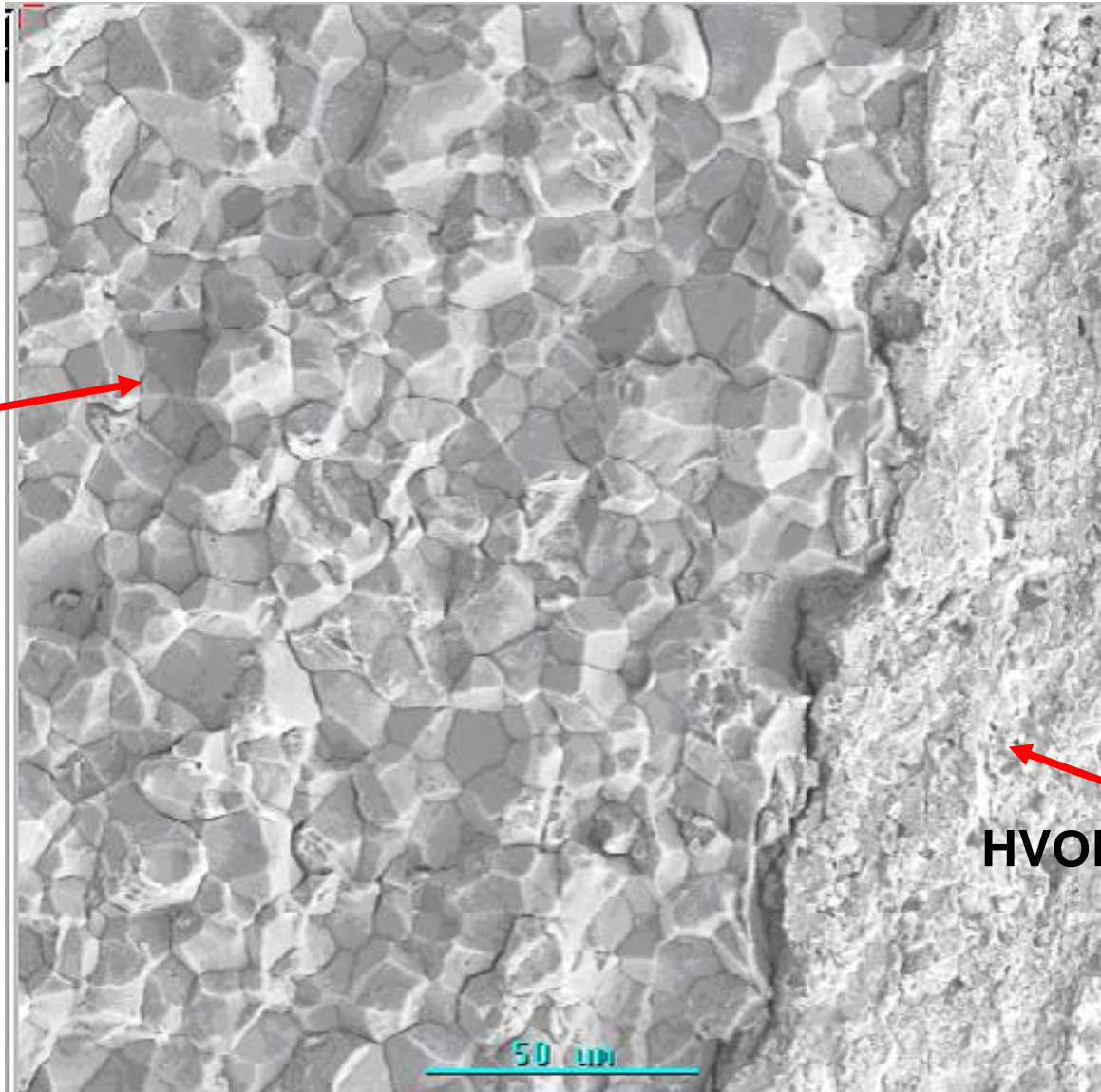
Discoloration of substrate under cracks in WC-17Co coating



**Intergranular region
consistent with embrittlement**



Substrate



HVOF WC-17Co



Status



- Testing of WC-17Co / cadmium coated specimen being completed “as we speak”
- Metallurgical analysis to determine the exact cause of failures is ongoing
- Final report Dec 04



Metal Coated Particles Proof of Concept Evaluation



Metal Coated Particles Evaluation



This approach may improve the ductility of HVOF WC-17Co coatings and enhance coating integrity

- Federal Technology Group will nickel plate 5 micron WC particles
- Coating WC particles with cobalt probably a better choice, but too expensive for this limited evaluation
- Sulzer-Metco will agglomerate WC particles into 45 micron clumps for making WC-17Co powder
- AFRL will provide 1/4" diameter, 4340 steel, Rc53 fatigue specimen and evaluate coating integrity